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An approach to environmental impact study in the Kakinada bay

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Introduction

Studies on the hydrography, current patterns and upwelling, faunal distributions, fisheries, plankton and primay productivity and so on, have been carried out in different estuarine water systems of India for years past (Kemp, 1915; Sewell and Annanadale 1972; La Fond, 1954; Satyanarayana Rao, 1957; Ganapati and Ramasarma, 1965; Ramasarma and Ganapati, 1968; Jhingran and Natarajan, 1969; Rajyalakshmi, 1972 and 1975; Rajyalakshmi, and De, 1979, among others on the studies in the East Coast of India). These water bodies have been the mainstay for fisheries, for food and employment. In recent years, however, the emphasis on this broad use of the water has been shifted to its utilization for other activities such as dumping effluents from various industries and sewage and urban wastes. Therefore it has become important now that every time a use has been made or is envisaged for a limited or unlimited water body, an environmental impact study is done using a comprehensive approach. Such a study would lead to a better management of the system as a whole. This

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impact study in general is an abatement approach because *in general* in India now, there are no water regulations for any user.

With the abatement approach in view, the authors have commenced a preliminary study on environmental impact in the Kakinada Bay with a small grant provided by the Andhra Pradesh State Board for the prevention and control of water pollution during 1981-83.

A few approaches have been applied: A. Traditional studies on hydrography and biological status of the bay; B. Tissue and sediment analysis to study toxic effects; and C. An analysis of the present status of the standing crops. Areas of high, medium and low impacts resulting from the various onshore activities and bay uses are shown diagrammatically.

Materal and Methods

Physiography of the study area

The Kakinada Bay situated between 82°15′ E and 82°22′ E Longitude and 16°51′ N and 17°N latitude is a small coastal feature on the mid-east coast of India. The bay is approximately *132 sq. km in* extent bounded on its western edge by the mainland. On its east a 16 km long narrow sand bar is present taking origin and extending from the eastern tip of the Hope island separating the bay from the sea. On its north to north east, the bay opens to the Bay of Bengal by a wide mouth. On its southern and south western edge the bay is connected to the Godavari estuarine complex through a number of inter-connecting creeks and a few narrow rivers which traverse through the mangroves (Fig. 1).

Bottom topography and sediments

The depth charts do not indicate any wide or sudden fluctuations in the profile of the bottom topography. The bottom sediments are composed of sand, silt and clay in the finer fractions and shell fragments, wood material, terrigenous mineral and foraminifera composing the large fractions. Only one area, the Kakinada canal area is recognized as a rocky zone being boulder-lined. The major part of the bay is silty clay bed with occassional sand patches near the sand spit. Silty clay prevails opposite the mouths of drains and canals at the south and west.

Tides, waves and surface drift in the Kakinada Bay:

The hydrodynamics of the bay and the adjacent Bay of Bengal have been studied by La Fond, 1954; Satyanarayana Rao, 1957 and Ramasarma and Ganapati, 1968. The tides are semi-diurnal. The maximum spring tide is 1·8 m and the minimum neap at-0·18m. A sand spit on

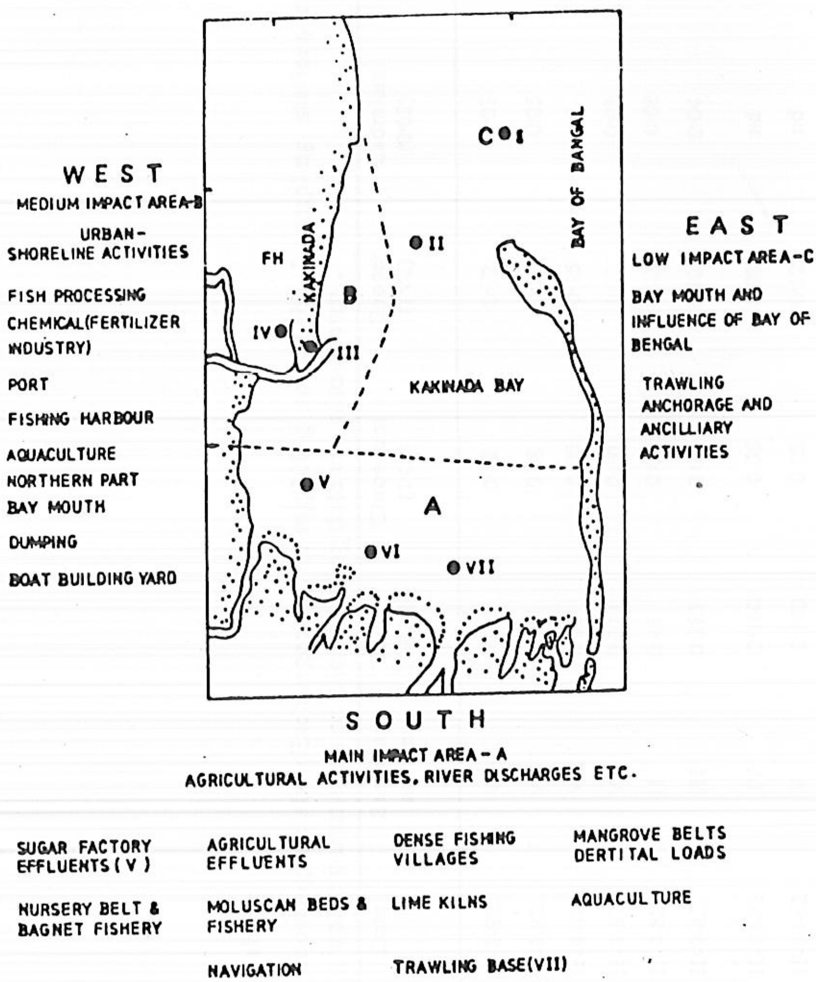

Fig. 1 Showing activities and areas of main, medium and low impacts in Kakinada bay.

Table :

Showing metals (Exchangeable) in mg/100 g soil at the 7 sampling stations in different months (other hydrographic parameters on the sampling date are also shown).

Date	Sampling station	Zinc (1 025)	Chromium (1·02)	Copper (1·02)	Cadmium (0·02)	Depth (m)	Temp. (°C) (Bottom)	Sal. (ppt) (Bottom)
30-8-82	V	0·302	0·12	0·12	0·03	1·5	28·0	15·06
16-9-82	VI	0·281	0·08	0·28	0·05	1·1	30·8	12·65
16-9-82	VII	0·18	0·05	0·15	nd	1·54	30·8	12·05
16-9-82	V	0·329	0·10	0·31	0·08	1·55	29·9	12·65
23-9-82	II	0·48	0·08	0·13	0·08	7·0	21·07	29·9
30-9-82	III	0·383	0 07	0·10	0·04	1·73	30·5	14·76
10-10-82	IV	0·180	0 06	0·08	nd	0·45	34·0	18·07
15-10-82	V	0·190	0 08	0·12	nd	1·4	29·9	25·28
15-10-82	VI	0·272	0·08	0·34	0·02	1·0	29·9	24·98
15-10-82	VII	0·224	0·08	0·17	0·02	1·4	29·9	31·6
25-10-82	IV	0·253	0·09	0·10	nd	0·4	34·0	5·44
25-10-82	III	1·54	0·12	0·21	0·06	1·9	30·1	5·74

(Continued)

(Contiue)

20-11-82	V	0·224	0·08	0·23	0·05	1·9	27·2	29·19
20-11-82	VI	0·256	0·08	0·21	nd	1·8	27·0	32·5
20-11-82	VII	0·21	0·06	0·25	nd	1·5	26·6	29·8
19-2-83	V	0·296	0·08	0·32	0·08	1·81	28·9	43·93
19-2-83	VI	0·344	0·09	0·33	0·07	1·5	28·4	47·54
19-2-83	VII	0·244	0·09	0·23	0·06	1·45	27·9	43·33
2-3-83	III	0·614	0·11	0·30	0·22	1·75	28·0	60·41
2-3-83	IV	0·192	0·03	0·11	nd	0·45	28·9	34·91
11-3-83	III	0·752	0·14	0·23	0·18	0·9	30·2	23·78
11-3-83	IV	0·458	0·05	0·07	0·09	0·25	31·4	14·16
14-3-83	I	0·385	0·12	0·45	0·09	25·0	27·0	61·9
14-3-83	II	0·426	0·07	0·26	0·11	7·0	26·9	60·71
2-4-83	III	1·077	0 12	0·34	0·31	1·2	28·5	52·65
2-4-83	IV	0·240	0·03	0·10	nd	0·42	29·9	40·92

nd : Not detected.

the eastern edge protects the bay and incidentally,limits the wave action. The waves entering the bay are refracted in such a way that they reach the southern and south-western sides and finally, before they reach the shore, loose much of their energy and do not produce any appreciable long shore currents (Bhavanarayana, 1974).

The surface drift, the general pattern of the littoral currents are mainly towards north during March to September and reverse during winter season and these factors influence the distribution inside the bay (Ramasarma and Ganapati, 1968). Although the sand-spit is found to be extending towards north, albeit at a slow rate (Varadarajulu *et al.* 1978), the Bay mouth has never been reported to be closed by any sand bar formations.

The bay is quite shallow especially on its southern and western sides with a depth of 1·8m during tides. The central and northern part have a depth range of 1·8m–9·5m.

With the construction of a 500 m long arm of the fishing harbour at the western edge of the Bay mouth, during 1983, the mouth area is now constricted.

Sampling stations and the sampling methods :

7 Sampling stations were identified in the bay (Fig.) on the basis of their location in relation to the broad uses of the Bay. The stations' location is arbitrary although fixed land marks are used to some extent.

The routine water and soil analysis are carried out in the Samalkot Agricultural Research Station of A. P. Agricultural University. sediment analysis for heavy metals etc. if any was carried out at CIFRI,s laboratory at Barrackpore by Atomic Absorption spectrometry.

The chlorinity was estimated by the standard titration method of Kundsen and salinities calculated from the Kundsen tables. Dissolved oxygen was estimated by the Winkler's method,

A sechi disc of 30 cm diameter was used for determining the transparency of the waters. The plankton collections were made with 1/2 meter dia. townet of organdie cloth (160 cm in length) in a 5 minute haul at

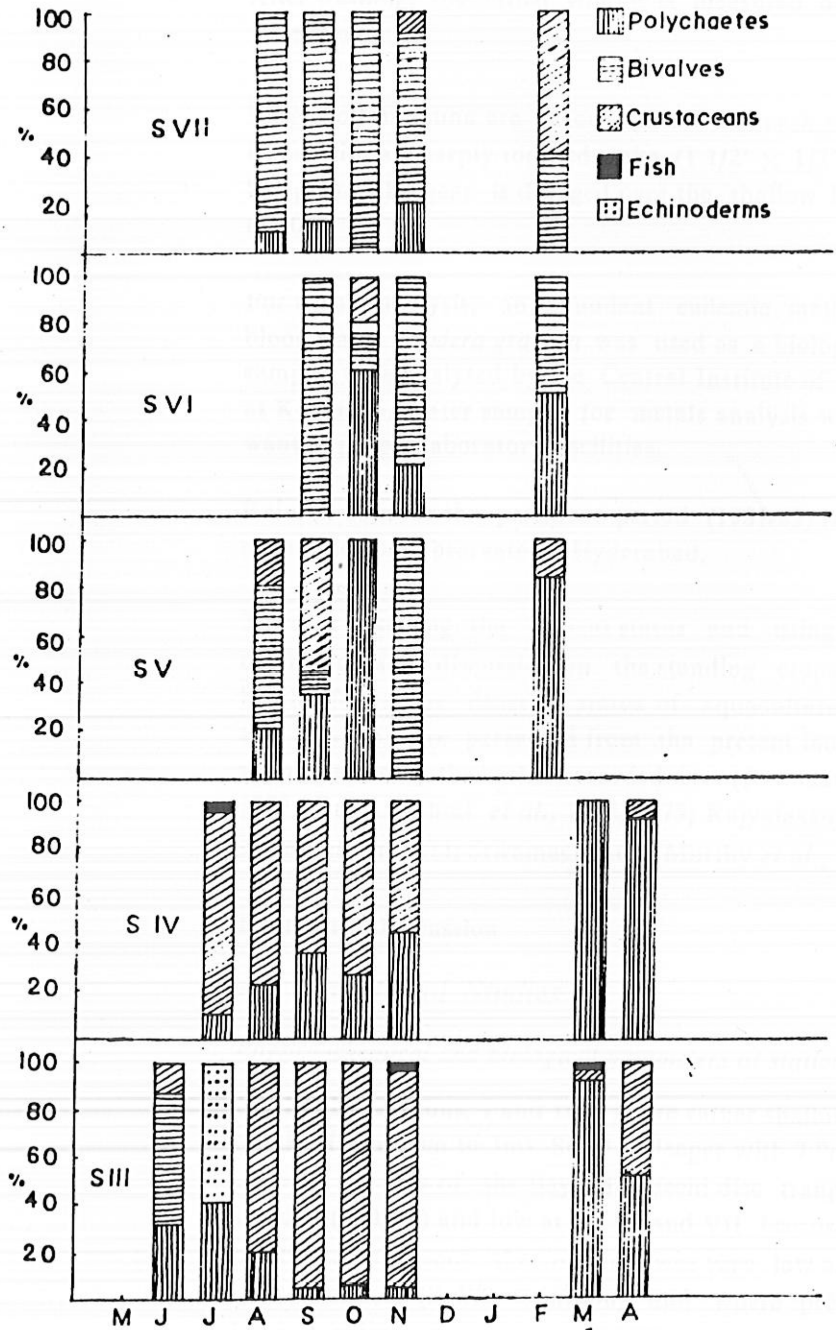

Fig. 2 Faunal composition of benthic macrofauna at stations III-VII.

a minimum speed of the out-board motor. Bottom fauna and soil samples were taken with a Ekman's dredge (dredge area 9052 cu cm). After washing, the settled volume is measured and numerical counts were made.

Large bottom fauna are taken with a 1 cm mesh net attached to a iron frame with a sharply toothed rake (1 1/2′ × 1/2′), the net bag length being 1m. This gear is dragged over the shallow bottom for a distance of 10m.

For tissue analysis, an abundant endemic mollusc of the Bay, the blood clam *Anadera granosa* was used as a biological indicator. The samples were analysed by the Central Institute of Fisheries Technology at Kakinada. Water samples for metals analysis were not taken due to want of proper laboratory facilities.

Rainfall data for the pertinent period (1981-83) is obtained from the meteorological observatory, Hyderabad.

Towards assessing the present status and using it as base line data, description and discussion on the standing crops such as the major benthic fauna, the fisheries, status of aquaculture, of mangrove nursery area etc., are presented from the present incidental observations supplemented by the earlier recorded data (Radhakrishna and Ganapati, 1977; Rajyalakshmi *et al.*, 1972, 1975; Rajyalakshmi and Reddy, 1982; Narasimham, 1973; Sriramachandra Murthy *et al.*, 1979.

Results and Discussion

A. *Traditional Studies*

Physico-chemical and biological parameters at stations I-VII

Most of the stations, I and III-VII are rather shallow (with mean depths ranging from 2·0m to 3m). St. II is deeper with 7·9m depth range being the open sea area of the Bay. The sechi disc tranparency is high at St. I and II (300 cm) and low at St. V and VII because of the shallowness, but in some seasons the reading was very low at 18 cm when flood waters entered (S. W. monsoon) and where productivity was high (Station VII).

All stations showed alkaline readings of medium to high. The temperature and salinity seemed to be governed by the large inputs of waters from the R. Coringa on the south and the wide mouth of the Bay to the Bay of Bengal on the north. Kakinada canal on the west also brings in considerable freshwater inflows. The main monsoon is the south-west (June–September) and a minor north-east one (December-February). The current status of the hydrography of the Bay is described briefly as follows : Little or no thermal stratification was found except at St. I, the surface and bottom temperature differing by 3° C only. The general temperature range was 26·3°C–34°C (surface) and 26-6° C–30·7°C (bottom). The St. IV however had a difference of 6°C being a shallow pond area where evaporating effect was high. Steep chemical gradation *is also absent indicating good mixing of* layers.

The salinity variations were generally very wide. The salinity is uniformly high in summer months at both surface and bottom waters (34 ppt) due *to* cessasion of fresh water inflows from south, increase in neritic waters from the north and to some extent, evapooration factors (due to the shallowness of the bay) as shown by the high values in some parts of the year (particularly February) in all the stations. During south-west monsoon (June to September) in the southern part of the Bay, *the salinity* is as *low* as 4·7 *to* 12·0 ppt. During winter (October-February) the values started rising showing a post-monsoon recovery. In the shallow areas the values reached as high as 60·7 ppt.

The *dissolved oxygen level remained* high (6·0-13 2 ppm) at all the stations except at St. III where it declined to below 5 ppm. Variations during seasons was quite high especially at stations III to VI and between surface to bottom it was around 1 ppm, the St. III, V & VI showing lower values at the bottom than at the surface waters. This could be *due to the accumulated detrital matter from* the drains and the respiration of the large beds of *Modiolus.*

Plankton : The density of total plankton ranged from 0·5 to 85 ml/ per operation.

Phytoplankton : The phytoplankton diversity is primarily diatoms and only 6-8 species were found. The St. I and III showed higher density than the St. V to VII.

Zooplankton : The Zooplankton population is composed of copepods, Mysids, Decapod larvae, Fish eggs, Polychaetes, Gastropod larvae, *Sagitta,* Foraminifera and Tintinnids. The polychaeta and gastropod larvae were more prevalent at St. V & VII. St. III had a highly characteristic Tintinnid population as also, Foraminifera. In general this station was richer in planktonic content than all others due to its location between the Inflows from the sea and canal and the nutrient loads from the dumpings from adjacent godowns. Both phyto and zooplanktons showed a bimodal distribution with a major peak during March-May and minor one during October-November.

Benthos: (Fig. 2) Benthos representing the biogenic capacity of the system showed the main differences between open Bay station I & II with sandy bottom and very little nutrient inflows; the farm (St. IV), with known nutrient inputs; western and southern stations (V-VII) where paddy drain effluents and other effluents from the populated villages along it are carried down. The station III, (where shipyard wastes and waste loads from the commercial canal are high) had highest density of benthic population, followed by the farm (St. IV) and St. V & VII. The overall density ranged from 3-4 806 *no.* 1 m².

Vascular plants : (Impact at St. V-VII): Large quantities of floating *Eichhornia crassipes* entered the Bay at St. V-VII, descending from the drain channels at the south (Rajyalakshmi, 1975). Perhaps this abundance can be related to the release of excess nutrients, particularly phosphates from the paddy field effluents. High P_2O_5 content was seen in the sediments at St. V & VI.

B. Sediment and tissue analysis

Sediment analysis : An attempt has been made to study the composition of the sediments at stations I-VII with particular emphasis on heavy metals, copper, zinc, cadmium and chromium. Of the four metals analysed cadmium and chromium were slightly on the higher side (Table 1). The sources of cadmium and chromium could be through the R. Godavari waters entering at the southern part, the minor port activities or the commercial canal in the south eastern side. Since the analysis of concentrations in water column have not been undertaken, this aspect cannot be fully interpreted

As biological indicator of toxic substances in the tissues, a typical species of the Bay, the blood clam, *Anadora granosa* prevalent in the environment at St. V–VII showed a slightly higher level of cadmium than normal.

Although consumptions of blood clam or any mollusc is not common in the Bay region, apart from this public health aspect, the Bay ecosystem itself may be badly effected by the introduction of high levels of heavy metals especially in view of the complex nature of its current and other hydrographic factors. In the shallow waters of the Bay where the coastal grasses, mangrove shrubs make a significant contribution to the total carbon input it is essential to reduce such inputs.

C. An analysis of the standing crops

1. *Some faunal distributions and their importance (Impact at St. III, V–VI)* :

The extensive inter-tidal mud flats at the mouths of all the drain channels on the southern part of the Bay provide obviously very favourable habitat for a small species of bivalve mollusc, *Modiolus*. These favourable characteristics of the Bay are : 1. Shelter from the open sea; 2. Contact with diluted sea-freshwater; 3. Wide tidal variation that leaves the mud flats and the beds exposed to the air for several hours between each tide. 4. Loose spongy base formed by old beds of *Modiolus*.

The earlier studies were on the systamatics and ecology of the bottom fauna of the Bay (Radhakrishna and Ganapati, 1968) and on the bottom faunal distribution (Bhavanarayana, 1974). The present study almost 2 decades later indicates a few important differences such, as for example, 1. The high density *Modiolus* beds mentioned above; 2. The presence and distribution of the blood clam, *Anadora granosa* in the north western, southern and midcentral part of the bay.

The increase in the agriculture operations along both sides of all the creeks and drains opening into the south and south western Bay has resulted in greater in-flow of silt-laden waters with greater nutrient load to the intertidal region and further into the Bay.

Another dominant mollusc of the Bay, the window-pane oyster *Placenta placenta* (Radhakrishna and Ganapati, 1967; Narasimham, 1973) forms a contiguous bed (Sriramchandra Murthy *et al.*, 1969). The regions of fine clay mixed with varying quantities of silt rich in organic carbon (as is evident at St. V-VII of the present study) are found to be most productive ones in the bay (Radhakrishna and Ganapati, 1967).

From the above it appears that species-specific molluscan fishery impact might be on the increase in the southern parts of the Bay.

2. *Fisheries (A major resource and use)* :

The Bay fisheries are a major source of food and the fishing is artisan as well as it is done with small mechanised trawlers, which started operations since 1964. The catches showed that the bay has marine-dominant species composition and all the species are transients. The trawling in general is towards the mouth area corresponding to St. I & II. The southern part of the Bay (St. V & VI) is fished by the bag type of gear in view of its being more a juvenile prawn/fish ground (nursery) and a major molluscan fishing ground. At St. VII again trawling is present. This shows that the entire bay is a major fishing base. The total landings by trawling (mechanised boats) alone was recorded to be at 16, 210 t in the 1982-83 period at the Kakinada fishing harbour. The bay fishing employs more than 30,000 fishermen.

The impacts of onshore activities on the fisheries have not been studied in detail so far. However, at St. VI (R. Coringa) fish kills and bad odour have been reported on the days when effluents from the sugar factories (located 30 km away at Chellur) are released.

The impact of fishery on the bay itself is by way of trawling which constantly disturbs the bottom conditions; loads of unwanted fish also are dumped into the system.

3. *Aquaculture (Impact relating to St. IV)* :

Aquaculture is a new feature of the bay uses. Currently, all the excavated brackishwater fish farms are on the north western part of the bay, in the reclaimed intertidal zone not extensive in acerage and situated at some distances from each other in a 40 km coastal stretch. The farms are only semi-intensive using both fertilization techniques as well as artificial feeding at a low level. None of the ponds use aeration systems and, release of water from ponds to the Bay could be twice in a month at low tides of the spring tide duration. The water retention time in a farm averages 15-20 days and water flow-in during the spring tide average 1-2 m^3 to a pond depth of 1 m.

The total production from all the farms on a maximum could be around 20t/year at present, the range being 0·3 t to 20t.

Conditions in the farms in regard to the volume, velocity and height of flow and ebb tides vary from season to season in relation to the fluctuations in the Bay. The environmental impact, in this case, from farm effluents, depends also on the management of the farm. Combined with the multiple uses of the bay water where the farms effluents are discharged, it is not quite evident at this stage whether the farms could yet be quite contributory to adverse environmental impact. At what level of increase in farm acreage (and hence water utilization) the critical level is reached when impact is felt, must be assessed yet. Margin must also be given for the possible expansion of the brackishwater aquaculture not only in the fringes (as existing today) but also to future development in the Bay itself (mariculture, by way of pens, cages etc.,).

4. *Mangrove systems (Impact relating to Sts. V - VII) :*

Mangrove ecosystems are known to be highly productive and in many areas are considered to be primary producers in estuarine food chains on which large commercial fisheries are based (Odum and Heald, 1975). The creeks/rivers at the southern end of the Bay drain extensive and thickly vegetated mangrove belts the large tree variety, the brush type or the submerged grasses. Almost all the rivers traversing these mangroves are quite deep and show no extensive siltation. Water currents also vary widely in these areas along with the tides except for the creeks connected to the R. Godavari (Ramasarma and Ganapati, 1968). There is also a steady salinity gradient.

The total area under mangrove bed might be more than 10,000ha around rivers and creeks draining to St. VI to VII. Some creeks (St. V) do not receive much flood water, therefore flow is directional towards the Bay exporting large amounts of vegetative detritus from the mangroves as shown in other studies elsewhere (Odum and De La cruz, 1967; Odum and Heald, 1975). Actual measurements of detritus production was however not done.

All the above characteristics seem to favour extensive prawn nursery system (McHugh, 1967). As reported by Ganapati and Subramanyam (1966), Rajyalakshmi (1972 and 1975), extensive juvenile prawn fisheries exist in the southern parts of the Bay. The smaller brush type vegetation adjacent to station IV-VII harbour postlarvae of particularly, *Penaeus monodon* (Rajyalakshmi and Reddy, 1982).

As shown earlier, in the recent decade there has been an organised reclamation of coastal land-particularly the mangrove-filled marshy intertidal zone at the north-western edges of the Bay for brackishwater aquaculture. The direct impact resulting from excavation is the loss of top soil and the mangroves, the latter of which act both as a rich feeding grounds and buffer zone against erosion and flood damage.

Conclusions

The lack of information, and methodology as is required from a multidisciplinary approach to the coastal environments results in our inability to predict with even 50% accuracy the effects of a particular action such as a construction of a structure or an establishment of an industry on the existing activities and status.

The Kakinada Bay is a typical estuarine system both "hydrographically and physiographically" (Ramasarma and Ganapati, 1968). Keeping the complex pattern of water circulation in the Bay in view, this small Bay is arbitrarily divisible into three broad areas to study interrelationships and impacts resulting from all man-made on-shore interferences and uses in the bay itself (Fig. 1).

So far no monitoring programmes are in operation in the Kakinada Bay which, as shown, is a multiple use system with high productivity indices. The type of approach to be used for an impact study, presented in this paper, has been drawn up to provide trend type of information plus such of those data which can be used as base-line information for assessment of a short or long-term hazards to the Bay without bias towards any single use. Management programmes for the Bay must be developed on this basis.

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